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(54) Title: METHOD AND APPARATUS FOR ESTABLISHMENT OF DYNAMIC ESCON CONNECTIONS FROM FIBRE CHANNEL FRAMES
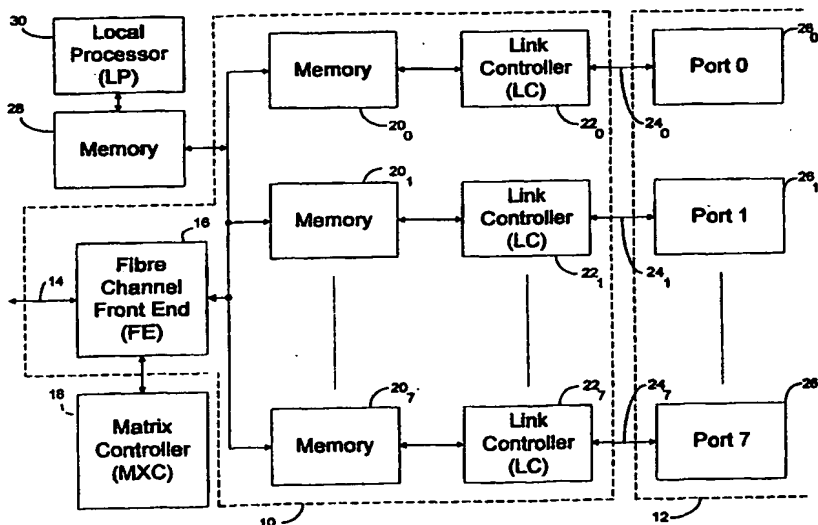
(57) Abstract

A method and apparatus for the establishment of dynamic Enterprise System Connection ("ESCON") (10) connections over a Fibre Channel Connection allows a port state machine (or port module) (26) to request dynamic ESCON connections from the exchange context of the Fibre Channel exchanges to ESCON ports while also linking and monitoring the status of these connections for all subsequent frames associated on a particular exchange. In a particular embodiment, the method and apparatus provides the ability to establish dynamic connections through an ESCON director switch (12) based off of the Originator Exchange Identifier ("OX_ID") of the FC–2 header and information contained in the FC–4 header of the Fibre Channel frame. Once a connection path has been established for a particular OX_ID, that connection is maintained until the exchange is terminated.

METHOD AND APPARATUS FOR ESTABLISHMENT OF DYNAMIC ESCON CONNECTIONS FROM FIBRE CHANNEL FRAMES

BACKGROUND OF THE INVENTION

The present invention relates, in general, to the field of

5   Enterprise System Connection (ESCON™ is a trademark of
International Business Machines Corporation, "IBM") switches. More
particularly, the present invention relates to a method and apparatus
for the establishment of dynamic ESCON connections from Fibre
Channel frames.

10   A typical ESCON switch is described in United States Patent No.
5,107,489 issued April 21, 1992 for "Switch and its Protocol for Making
Dynamic Connections", the disclosure of which is herein specifically
incorporated by this reference. Among the switches which are
commercially available are the IBM ESCON Director Models 3, 4 and 5

15   developed in conjunction with McDATA Corporation, Broomfield,
Colorado, assignee of the present invention. An ESCON connection
has a bandwidth of 20 Mbytes/sec. in a half duplex mode of operation.

On the other hand, Fibre Channel is an integrated set of
standards adopted by the American National Standards Institute

20   ("ANSI") which defines protocols for information transfer. The Fibre
Channel has a bandwidth of approximately 200 Mbytes/sec. (212
Mbytes/sec.) in full duplex mode of operation (i.e. 106 Mbytes/sec. in
each of transmit and receive modes of operation). Information transfer
occurs in indivisible units called "frames". Fibre Channel devices are

25   called "nodes", each of which has at least one "port" for access to other
ports of other nodes. Currently, fibre channel includes five defined
functional levels:

FC-0 defines the physical portions inclusive of media types,
connectors and the electrical and optical characteristics needed to

30   connect ports.;

FC-1 defines the transmission protocol, including the encoding, order of word transmission and error detection;

FC-2 defines the signaling and framing protocol inclusive of frame layout, frame header content and rules for use;

5   FC-3 defines common services that may be available across multiple ports in a node; and

FC-4 defines the mapping between the lower levels of Fibre Channel and the command sets that use it, inclusive of the Small Computer System Interface ("SCSI"), Intelligent Peripheral Interface ("IPI"), High Performance Parallel Interface ("HIPPI") and the like.

10

As previously mentioned, the standard ESCON connection has a bandwidth of 20 Mbytes/second and is half-duplex in operation (i.e. either a "read" or "write" command can be active at one time) while Fibre Channel can provide up to 212 Mbytes/second (106 Mbytes/second in both transmit and receive) at full duplex. It would, therefore, be highly desirable to be able to multiplex multiple ESCON channels over a single Fibre Channel connection to take advantage of the latter's much higher relative bandwidth.

15

20   **SUMMARY OF THE INVENTION**

The method and apparatus of the present invention advantageously allows a Fibre Channel port state machine (or port module) to request dynamic ESCON connections from the exchange context of the Fibre Channel frame and to implement dynamic linking of Fibre Channel exchanges to ESCON ports. The port level state machine also links and monitors the status of these connections for all subsequent frames associated for the duration of a particular exchange until exchange termination.

25

In a particular embodiment disclosed herein, the present invention provides the ability to establish dynamic connections through

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an ESCON Director switch based off of the Originator Exchange Identifier ("OX_ID") of the FC-2 header and information contained in the FC-4 header of the Fibre Channel frame. Once a connection path has been established for a particular OX_ID, the method and apparatus

5   of the present invention maintains that connection until the exchange is terminated.

The present invention is of particular utility in allowing ESCON traffic (Fibre Channel FC-4 type) to be transported and multiplexed with standard Fibre Channel functionality equivalent to that of eight

10 conventional ESCON channels. The method and apparatus of the present invention allows for connections to native ESCON devices to be established throughout an ESCON Director switch and the multiplexing of these connections through the use of Fibre Channel frames and sequences.

15 Particularly disclosed herein is a method for multiplexing a plurality of first data channels over a second data channel. The method comprises the steps of indicating a start up exchange for a first of a plurality of data frames on the second data channel, directing the first of the plurality of data frames from the second data channel to a

20 specified one of the first data channels and also directing all subsequent ones of the plurality of data frames to the specified one of the first data channels.

Also disclosed herein is a port module which comprises a plurality of link controllers, each of the link controllers coupled to one of

25 a plurality of data ports; a plurality of buffer memories, each of the buffer memories associated with each of the link controllers; a data channel; and a front end portion of the port module coupled to the data channel and operative in association with a matrix controller for identifying a start up exchange for a first of a plurality of data frames

30 on the data channel. The front end portion directs the first of the

plurality of data frames to a first portion of the plurality of buffer memories and all subsequent ones of the plurality of data frames to a second portion of one of said plurality of buffer memories associated with one of the link controllers associated with a selected one of the

5   plurality of data ports specified by the matrix controller.

In a more particular embodiment of the present invention, a method is disclosed for establishing dynamic ESCON connections over a Fibre Channel connection. The method comprises the steps of: receiving a series of Fibre Channel data frames on the Fibre Channel

10   connection, checking each of the series of data frames for a status of an Originator Exchange Identifier and linking the Originator Exchange Identifier to a selected one of a plurality of link controllers each coupled to one of the ESCON connections. The data frame is then passed to the selected one of the plurality of link controllers if the status of the

15   Originator Exchange Identifier of a first of the series of data frames is in an inactive state thereof and the state of said Originator Exchange Identifier is changed to an "active" state thereof. Each of the series of data frames having a corresponding Originator Exchange Identifier is passed to the selected one of the plurality of link controllers while the

20   status of the Originator Exchange Identifier is in the "active" state thereof and the state of said Originator Exchange Identifier is re- changed to the inactive state thereof upon receipt of a last of the series of data frames having the corresponding Originator Exchange Identifier.

25

BRIEF DESCRIPTION OF THE DRAWINGS

The aforementioned and other features and objects of the present invention and the manner of attaining them will become more apparent and the invention itself will be best understood by reference

to the following description of a preferred embodiment taken in
conjunction with the accompanying drawings, wherein:

Fig. 1 is a functional block diagram of a port module in
accordance with a specific embodiment of the present invention for the
5   establishment of dynamic ESCON connections from Fibre Channel
frames illustrated in conjunction with a conventional eight port module
of an ESCON Director point-to-point switch;

Figs. 2A and 2B are a logic flow chart of the functionality of the
port module of Fig. 1 illustrating the processing of Fibre Channel
10   frames following FC-2 validation and the linking of the frame OX_ID to
a particular link controller ("LC", or ESCON engine);

Fig. 3 is a representative buffer descriptor format for the memory
devices (for example 32K x 36 memories) associated with each of the
link controllers of the port module; and

15   Fig. 4 depicts a representative buffer descriptor memory map as
viewed by an individual link controller.

DESCRIPTION OF A PREFERRED EMBODIMENT

With reference now to Fig. 1, a port module 10 for the
20   establishment of dynamic ESCON connections from Fibre Channel
frames is shown. The port module 10 is utilized in conjunction with a
conventional ESCON point-to-point switch 12 such as the IBM Director
series Models 3,4, and 5 manufactured by McDATA Corporation,
Broomfield, CO.

25   The port module 10 receives data frames on a Fibre Channel
("FC") bus 14 which is bidirectionally coupled to a Fibre Channel front
end 16. As mentioned previously, the Fibre Channel bus 14 has a
bandwidth of approximately 200 Mbytes/sec. in full duplex mode (100
Mbytes/sec. for transmission and 100 Mbytes/sec. for reception). The
30   Fibre Channel front end ("FE")16 operates in accordance with

instructions received from a matrix controller ("MXC") 18 which
specifies which of the link controllers 22_0 through 22_7 to which to direct
a frame based upon the Originator Exchange Identifier ("OX_ID"). In a
preferred embodiment, the matrix controller 18 may be furnished in a

5   form as described and claimed in co-pending United States Patent
Application Serial No.: 08/942,506 filed October 2, 1997 for: "Method
and Apparatus for Implementing Hunt Group Support for a Crosspoint
Controller", assigned to McDATA Corporation, the disclosure of which
is herein specifically incorporated by this reference. Once a "bind" has

10   been established to a particular one of the link controllers 22_0 through
22_7, all subsequent frames with the same exchange identifier are
automatically routed to the correct link controller 22 by the Fibre
Channel front end 16 as will be more fully described hereinafter.

The port module 10 further comprises a plurality of memory

15   buffers 20_0 through 20_7 each associated with a separate ESCON
engine (or link controller "LC") 22_0 through 22_7 respectively. The link
controllers 22 function to convert Fibre Channel sequences into
ESCON frames and vice versa. The link controllers 22_0 through 22_7 are
individually associated with a corresponding port 26_0 ("Port 0") through

20   26_7 ("Port 7") of the point-to-point switch 12 and are coupled thereto by
means of a corresponding number of ESCON buses 24_0 through 24_7.
Each of the ESCON buses 24 is capable of providing a bandwidth of up
to 20 Mbytes/sec. in half duplex mode. Through use of the present
invention (as an example only) eight ESCON channels (i.e. up to 160

25   Mbytes/sec. of data) may be multiplexed over a single Fibre Channel
bus 14 provided no more than 106 Mbytes/sec. of "reads" or "writes"
are presented at any one time. If this limit is exceeded, that is all eight
commands were, for example, "reads", the effective ESCON traffic is
then restricted to 106 Mbytes/sec. A local processor ("LP") 30 and

30   associated memory buffer 28 is also associated with the port module

10 as will be more fully described hereinafter. The LP 30 is
responsible for all Fibre Channel Basic Link Services, Extended Link
Services, Error/Exception Processing and any non-FC-4 requirements.

    With reference additionally now to Figs. 2A and 2B, the flow
5   chart illustrated depicts the processing of frames received from the
Fibre Channel. The starting point of the process 100 shown is assumed
to be after the FC-2 frame header validation which may require a data
structure access (i.e. active OX_ID table) entry such as SEQ_ID and
SEQ_CNT validation for an "open" Exchange.

10   Following receipt of a Fibre Channel frame header at step 102,
the process 100 proceeds to perform FC-4 processing at decision step
50 (Fig. 2B). If the frame header indicates an FC-4 frame, then the
process 100 returns directly to decision step 104 (Fig. 2A). Otherwise,
at step 52 the frame is forwarded to the LP 30 as the frame is an FC-2
15   extended or basic link service frame. At decision step 54, if the frame
is valid, the descriptor is passed to the LP 30 at step 56, otherwise the
LP 30 descriptor is reclaimed at step 58.

    At decision step 104, an OX_ID look-up table, LUT, is used to
identify if an Exchange is currently "active". (The FC-2 layer, through a
20   common data structure in the TX_LUT, validates if an Exchange is
"active". If it is, it compares the SEQ_CNT of the Exchange and the
SEQ_ID of the received frame to the previously stored values for the
OX_ID to determine if it is the next sequential frame of a sequence or a
new sequence. If the Exchange is "active", then the process 100
25   proceeds to step 106 where a second look-up is performed to identify
the link controller 22 (or ESCON engine) that is bound that Exchange.
(It should be noted that the process of decision step 104 and step 106
are actually performed in parallel but are illustrated as separate steps
for sake of clarity.) This secondary check is also against the TX_LUT
30   information to determine if, for example, if SEQ_CNT = N+1, SEQ_ID =

the stored SEQ_ID etc. The received frame is then forwarded to that
link controller 22 cut-through descriptor at step 106. At decision step
108, if the frame is not valid, the cut-through descriptor is reclaimed at
step 112 and the process 100 returns to step 102. Alternatively, the
process 100 proceeds to step 110 and the cut-through descriptor is
passed to the bound link controller 22.

Each descriptor contains a complete sequence and ownership is
only passed at the termination of the sequence. A buffer pointer is
maintained within each cut-through descriptor for subsequent frames of
a sequence.

At decision step 114, if the F_CTL field bits (19,20) indicate the
last sequence of the Exchange (Exchange Termination) then the OX_ID
is "closed" at step 116 and the binding between that OX_ID and the
selected link controller 22 is released and the process 100 returns to
step 102 to receive a Fibre Channel frame. If Exchange Termination is
not determined at decision step 114, the process 100 updates the
associated Look-Up Table ("LUT") entries SEQ_CNT, SEQ_ID, etc. and
returns to receive the next Fibre Channel frame at step 102.

If at decision step 104 the OX_ID is not "active", then the
process 100 proceeds to step 118 where the OX_ID is set to "open"
and the frame is broadcast to the same start-up descriptor of all link
controllers 22. At decision step 120, a determination is made as to
whether or not the frame is valid. If it is, then a queue request is
issued to the MXC at step 122. The ESCON link address of the device
is extracted from a predetermined FC-4 header location within the FC-2
payload. If it is not valid, then at step 124, the OX_ID is "closed" and
the start-up descriptor is reclaimed and the process 100 returns to step
102 to await the next frame.

If at decision step 126 the MXC 18 processing results in either a
busy ("BSY" i.e. a destination busy "DST_BZ") or reject ("RJCT" i.e. a

port reject "PRT_RJCT") condition then the process 100 proceeds to step 128 where the OX_ID is "closed" and a busy/reject indication frame is returned to the Fibre Channel with a return to step 102. Alternatively, if the MXC 18 response is neither a busy nor a reject

5   condition, then the OX_ID is set to "active", the OX_ID is bound to a particular one of the link controllers 22_0 through, as indicated by the MXC response, 22_7 and the start-up descriptor is passed to that link controller 22 at step 130. The process then returns to step 102 to await the next Fibre Channel frame.

10   In operation, the apparatus and method of the present invention serves to guarantee in-order delivery of frames/sequences transmitted by a Fibre Channel Host (not shown) via the bus 14 to a particular one of the link controllers 22_0 through 22_7 through the "binding" of Exchange Identifiers to an individual link controller 22_0 through 22_7 as

15   shown in Fig. 1. The port module 10 logically binds the OX_ID of received frames from the host channel to a given link controller 22_0 through 22_7. When a new Fibre Channel frame has been received by the port module 10, the OX_ID is copied from the frame header and presented to the Look-Up Table. It should be noted that the port

20   module 10 actually performs various frame validations before actually using the OX_ID. The output of the LUT indicates the state of the OX_ID, as "opened" (i.e., FC-2 validated and MXC 18 bind pending), "active" (i.e., an active bind exists between the OX_ID and an LC 22) or "closed" (i.e., all other conditions). If the state is "active", the link

25   controller 22_0 through 22_7 number to which this OX_ID is "bound" is also output by the LUT.

If the OX_ID of a new frame is currently in the "closed" state, then the LUT entry for this OX_ID is updated to reflect the "open" state. The frame is then forwarded to a start-up descriptor buffer as will be

30   more fully described hereinafter. The FC-4 header of this frame is

validated and the ESCON destination link address (ED_ID) is copied
from the FC-4 header. If the FC-4 header checks validate, then a
request is then issued to the MXC 18 using pre-initialized Port Number,
Source Address, and the copied ED_ID. The MXC 18 processes the

5   request as disclosed in the aforementioned patent application and
returns the results back to the port module 10. If the results indicate
either a connection has been established or a dialog-2 condition, the
number of the particular one of the link controllers 22_0 through 22_7 is
indicated as part of the results returned by MXC 18. The port module

10   10 then updates the LUT to indicate the "active" state and link
controller 22 number bound to this OX_ID. The ownership of the start-
up buffer (the initial frame is "broadcast" to the same start-up buffer in
each of the buffer memories 20_0 through 20_7 of all link controllers 22_0
through 22_7) is then transferred to the appropriate link controller 22_0

15   through 22.

The "active" state of an OX_ID and binding between a specific
link controller 22 and the OX_ID remains intact until the F_CTL field
(bits 19,20) of a received frame indicates the termination of that
exchange. It is the responsibility of the host to close all exchanges it

20   has "opened". The LP, however, has access to the TX_LUT and can
perform exception processing when applicable. For exchanges that do
not transition to the "active" state the host can transmit a no operation
("NOP") type of frame to close the exchange or close the exchange by
some other means. The port module 10 must recognize this frame,

25   close the LUT entry and can flush the frame or the exchange can be
"closed" implicitly.

**Detailed TX Frame/Sequence Processing in an Exemplary
Embodiment of the Present Invention**

With respect to the flowchart of Fig. 2 previously described and a particular exemplary implementation of the port module 10 of the present invention, the assumption is that the link is up and operational for the transmission of Fibre Channel frames, i.e. in the Fibre Channel

5   "active" state. A basic assumption for any error type detected on FC-4 frames/sequences that are bound to a particular link controller 22 is that the descriptor is not passed to the link controller 22 until a sequence termination has been detected. Also the Fibre Channel front end ("FE") 16 is not responsible for detecting sequence timeout

10   conditions.

A look-up table (LUT) is used to store various information regarding outbound Exchanges from the Fibre Channel. The following are the definitions for this information.

LUT_ST	State of OX_ID. Three states have been defined, Closed, Open (MXC 18 request pending), and Active (Bind has been established)
LUT_BIND	Group Member (link controller 22) that the OX_ID has been bound to.
LUT_SEQ_ID	FC-2 Sequence_ID from the last frame received on this Exchange.
LUT_SEQ_FLG	This flag indicates whether a Sequence on this OX_ID is Active or Terminated.
LUT_SEQ_CNT	For multi-frame Sequences this is the last FC-2 Sequence Count received.
LUT_ERR	This flag indicates whether an error has been detected on the current Sequence.

15

FC-2 Frame Validation Processing

Initially, the FE 16 validates that a Start of Frame ("SOF") delimiter type has been detected. Any SOF delimiter type other than a Class 3, SOFi3 or SOFn3, is forwarded to the LP 30. If the SOF is

Class 3, then the FC-2 header must be processed. The FC-2 header
checks then follow and may be sequential or the FC-2 header captured
and performed in parallel. A R_CTL routing field check is performed
and, if the routing control field is anything other than an FC-4 Device,
5   bits 31:27 = 0x0, the frame is forwarded to the LP 30.

The D_ID and S_ID checks are then performed. The FE 16
validates the 24 bits of the D_ID against the Destination Address
Register and the 24 bits of the S_ID against the Group Base Address
registers. IF any miscompares are detected (including well known
10   addresses), the frame is forwarded to the LP 30.

The remaining FC-2 header checks are performed thereafter.
The Type field is tested against the FE 16 Type Register, the RX_ID
against 0xFFFF, and the DF_CTL field against 0x00. If any of these
checks fail, the frame is forwarded to the LP 30. If the OX_ID equals
15   0xFFFF, the frame is also forwarded to the LP 30. At this point, the
FC-2 CRC is validated for the Frame. If a CRC error is detected, the
buffer descriptor used is reclaimed by the FE 16 and the CRC error is
logged. If the FC-2 CRC validates, the descriptor entry for that buffer
is updated and ownership of the descriptor is passed to the LP 30. If a
20   Fibre Channel frame passes all of the checks, the gate of being able to
be forwarded to the LP 30 has been passed. Failure on any
subsequent validity tests will result in the frame being flushed and the
appropriate error logged.

25   **FC-4 Start-up Exchange Frame/Sequence Validation**
Processing
The FC-4 validation includes the OX_ID being tested for an
"active" state. If the OX_ID is not "active", a delimiter/F_CTL test is
performed for a single frame, first sequence of a new Exchange. If this
30   test fails, a secondary test is performed to determine if the frame is

terminating an Exchange in response to a Busy/Rejected command
frame. In either case, the frame is flushed but if the test fails, a
delimiter error is logged in the FE 16.

If the test passes, the F_CTL field is validated against a mask

5   value and the SEQ_CNT is set to 0. Failure of these tests logs a frame
content error and the frame is flushed. If these checks pass, a test
determines if the maximum number of outbound Exchanges have been
exceeded. If the maximum number of outbound Exchanges has been
exceeded, the error is logged and the frame is flushed. On the other

10   hand, if the test is passed, the FC-2 payload is broadcast by the FE 16
to the next available start-up descriptor As the frame is being
broadcast, the FC-4 header LRC is validated and failure of this check
causes an LRC error to be logged, the frame gets flushed and the start-
up descriptor buffer is reclaimed.

15   If the FC-2 CRC does not validate, the CRC error is logged, the
frame is flushed and the FE 16 reclaims the start-up descriptor. If this
test passes, the EOF delimiters are then tested for sequence
termination. If the delimiter is not an EOFt, a delimiter error is logged,
the frame is flushed and the start-up descriptor is reclaimed. If the

20   delimiter is an EOFt, a bind request is issued to the Matrix Controller
("MXC 18"), a LUT entry is created for this OX_ID and the LUT_ST
transitions to "open".

The results of the MXC 18 bind request are tested and if the bind
could not be established, a FC-4 BSY/RJT single frame Exchange is

25   generated and returned to the Fibre Channel, the LUT_ST of the
OX_ID is changed from "open" to "closed" and the start-up descriptor is
reclaimed by the FE 16. If a bind has been established, then the LUT
control block entry is updated, the LUT_ST transitions to "active" and
the start-up descriptor is updated and passed to the selected link

30   controller 22 as indicated by the MXC response.

FC-4 Cut-Through Frame/Sequence Validation Process

After a bind has been established between an LC 22 and an
OX_ID, all subsequent frames and sequences on that Exchange are
5   validated for error conditions and forwarded through to the cut-through
descriptor space for the duration of the Exchange. The cut-through
descriptors operate as a set of circular ring buffers. The LUT contains
several state information regarding the current state of a particular
Exchange, such as whether any errors, LUT-ERR, have been detected,
10   the Sequence ID, LUT_SEQ_ID, the Sequence Count, LUT_SEQ_CNT,
of the last frame received and a flag, LUT_SEQ_FLG, indicating
whether the Sequence ID is still active or terminated.

When a new frame is received and the OX_ID state is active, a
test is performed on the start of frame delimiter and the F_CTL field of
15   the frame against the LUT information. These tests provide checks to
validate that the received frame is consistent with respect to the LUT
information. If a new Exchange with the same OX_ID value is indicated
and the LUT_ST is active, an error is reported in that the frame to
terminate the Exchange was not received. If the frame indicates that it
20   is a continuation of a sequence but the LUT_SEQ_FLG is not active, an
error is detected indicating that the frame initiating the new sequence
was not received. Likewise, if the frame and F_CTL field indicates a
new sequence but the LUT_SEQ_FLG is active, then an error is
detected indicating that the sequence terminating frame was not
25   received. If the frame indicates an intermediate or terminating frame of
a sequence and the LUT_SEQ_FLG is active, then the LUT_SEQ_ID is
tested against the SEQ_ID field of the FC-2 header for consistency and
an error is posted. A continuously incrementing SEQ_ID algorithm may
be used for sequences consisting of multiple frames. If the SEQ_ID of
30   the received frame is not "n+1" from the LUT_SEQ_CNT for

intermediate or terminating frames of a sequence, then a missing frame error is reported. Any error detected during the processing of a sequence or a frame within a sequence is saved as part of the FC-4 Flags and sets the LUT_ERR flag in the absence of any frame FC-2

5   CRC errors.

Ownership of cut-through descriptors is indicated as part of the descriptor control field of a descriptor. During normal operations sequence size is negotiated such that each cut-through descriptor is sufficient in size to hold a complete sequence of frames. At the

10   detection of sequence termination, the FE 16 passes ownership to the cut-through descriptor to the LC 22 and indicates any of the detected error conditions through the use of the FC-4 Flags. Also at sequence termination, the appropriate LUT information is also reset, i.e. LUT_SEQ_IF, LUT_SEQ_CNT, etc.

15

FE Frame/Sequence Generation

The FE 16 is responsible for FC-2 header creation for all link controller 22 sequences. Through a set of registers, the FE 16 is allocated a unique range of OX_ID and SEQ_ID values for each link

20   controller 22. The link controller 22 provides an indication as part of the descriptor control field as to the initiation or termination of an Exchange and the R_CTL information category for each Sequence. With this information and a set of constants, i.e. RX_ID, Type, CS_CTL, and the like, the FE 16 is able to generate the FC-2 header

25   information. The following describes how the FE 16 can produce the various fields of the FC-2 header.

SOF Type   SOF3i for the first frame of a Sequence, SOF3n for all
                    subsequent frames of that Sequence.

R_CTL(31:28)

R_CTL(27:24) R_CTL (31:24)	Initialized in the descriptor control field.
D_ID	Initialized as a part of the FE 16 register set.
CS_CTL	Fixed.
S_ID	Initialized as a part of the FE 16 register set.
TYPE	The value in the FE 16 Type register is used for all frames.
F_CTL(23:22)	Fixed.
F_CTL(21:19)	Calculated based off of IU_CTL and Byte Count values from the buffer descriptor.
F_CTL(18:0)	Fixed.
SEQ_ID	The LP 30 through initialization of FE 16 registers provides a unique range of SEQ_IDs for each link controller 22. These values continuously increment and can wrap.
DF_CTL	Fixed.
SEQ_CNT	The SEQ_CNT for the first frame of each Sequence always starts at zero and increments for each additional frame of that Sequence.
OX_ID	The LP 30 through initialization of FE 16 registers provides a unique range OX_IDs for each link controller 22. These values continuously increment and can wrap. 0xFFFF is invalid and is not used as an OX_ID value.
RX_ID	Fixed.
Parameter	Fixed.
EOF Type	Based off o the number of frames required to be transmitted for each descriptor. For the last frame of a sequence EOFt is transmitted, otherwise, EOFn is used for all other frames of the Sequence.

When the FE 16 has detected ownership of a buffer descriptor, it creates the FC-2 header information as previously described. A test is made for the availability of the Frame Generator RX_FG. When the RX_FG becomes available, the FE 16 forwards the first frame of the FC

5   Sequence for transmission. If the byte count of the Sequence requires multiple frames, the FE 16 waits for the RX_FG to complete the transmission of the current frame and then immediately forwards the next frame, until Sequence termination. At Sequence termination, the FE 16 again begins polling the current buffer descriptor of the next

10   enabled ring.

       With reference additionally now to Fig. 3, the RX/TX buffer descriptor format for a representative one of the memory devices 20 is shown comprising a Descriptor Control Field, FC-4 Flags, FC-4 Header and Descriptor Buffer Area (Frame Data) regions. Each link controller

15   22 has an associated individual memory device which may be furnished as a 32K x 36 integrated circuit memory device, for each receive ("RX") and transmit ("TX") buffer descriptor area which are viewed by the link controller 22 as a single contiguous address space. The FE 16 views this memory as individual RX and TX memory regions. In the

20   embodiment illustrated, the address format is byte oriented and parity is implied on a per byte basis.

       The Fibre Channel frame information is the point of reference for these buffers. That is, the TX buffers contain outbound data that has been transmitted by a Fibre Channel Host while the RX buffers contain

25   inbound data that is received by the Fibre Channel Host.

Descriptor Control

Word 0 of each descriptor is the Descriptor Control (DESC_CTL) which provides the mechanism for transferring ownership of a particular

5   buffer descriptor. The local processor ("LP") 30 is responsible for proper setting of the ownership bits in all of these buffer descriptors at initialization. During error recovery actions or LC updates, the link controller 22 is responsible for proper lean up and initialization of these descriptors as the LP 30 has no access mechanism to the link

10   controller 22 descriptor memory while the Fibre Channel Link is operational. After initialization, the link controllers 22 "own" all of the RX buffer descriptors and the Fibre Channel front end ("FE") 16 "owns" all of the TX buffer descriptors. Various control and information is included within this field such as the algorithm for setting bits to pass

15   ownership, the amount of data associated with payload for this descriptor and other control-type information.

FC-4 Flags

The FC-4 Flags field, word 1, is used only by the FE 16 for the

20   TX buffer descriptors to indicate various FE 16 detected error conditions, as previously described.

FC-4 Header

The FC-4 header is used to store information that can describe

25   attributes associated with the payload.

Payload Area

The Payload Buffer area of the buffer descriptor contains the FC-4 level user data to be sent/received between the Fibre Channel Host

30   and LP 30/link controllers 22.

With reference additionally now to Fig. 4, the buffer descriptor memory map is depicted as viewed by an individual link controller 22. The buffer descriptor memory has a number of TX Start-up Descriptors 0 through N, a number of TX Cut-Through Descriptors 0 through N and

5   a number of RX Descriptors 0 through N wherein N may be a different number in each instance as selected for the particular design.   On the TX side (outbound from the Fibre Channel) this format allows for up to, in the particular exemplary implementation shown, eight single frame exchange start-up sequences to be issued. However, the

10   descriptor size is identical to the cut-through descriptors.

When the link controller 22 is in an "idle" state, it polls the Descriptor Control ("DESC_CTL") field of the Start-up Descriptor 0 testing for ownership. A pointer to the start-up descriptor "owned" by this link controller 22 is included in the Descriptor Control field. The

15   pointer address is byte oriented, word aligned (i.e. bits 1:0 have a value of b'00). The remaining descriptor information is included in word 0 of the start-up descriptor owned.

After the link controller 22 has operated on the start-up descriptor it then begins to poll the DESC_CTL field of its current TX

20   cut-through descriptor for its next TX sequence from the Fibre Channel. When the link controller 22 begins to operate on the cut-through descriptors it does so in a circular fashion, i.e. it uses the next sequential cut-through descriptor and wraps back to TX cut-through descriptor 0 after operating on TX cut-through descriptor 21. When the

25   link controller transitions back to an "idle" state, it again begins to poll the first word of start-up descriptor 0 for ownership.

The link controller 22 and LP 30 operate on the RX descriptor list as a circular ring of buffers. The FE 16 polls all of the RX descriptor rings in a "round robin" fashion testing for ownership of an RX

30   descriptor. When ownership has been detected, the FE 16 transmits

that descriptor inbound to the Fibre Channel and continues its round robin poll. After initialization or any error recovery actions on a particular link controller 22 or an software update to the link controller 22, the FE 16 resets its TX and RX cut-through descriptor pointers

5   associated with that particular link controller 22 to the first cut-through descriptor.

While there have been described above the principles of the present invention in conjunction with a specific system architecture and frame processing method, it is to be clearly understood that the

10   foregoing description is made only by way of example and not as a limitation to the scope of the invention. Particularly, it is recognized that the teachings of the foregoing disclosure will suggest other modifications to those persons skilled in the relevant art. Such modifications may involve other features which are already known per

15   se and which may be used instead of or in addition to features already described herein. Although claims have been formulated in this application to particular combinations of features, it should be understood that the scope of the disclosure herein also includes any novel feature or any novel combination of features disclosed either

20   explicitly or implicitly or any generalization or modification thereof which would be apparent to persons skilled in the relevant art, whether or not such relates to the same invention as presently claimed in any claim and whether or not it mitigates any or all of the same technical problems as confronted by the present invention. The applicants

25   hereby reserve the right to formulate new claims to such features and/or combinations of such features during the prosecution of the present application or of any further application derived therefrom.

What is claimed is:

CLAIMS:

1.   A method for multiplexing a plurality of first data channels over a second data channel comprising:

indicating a start up exchange for a first of a plurality of data

5   frames on said second data channel;

directing said first of said plurality of data frames from said second data channel to a specified one of said first data channels; and

also directing all subsequent ones of said plurality of data frames to said specified one of said first data channels.

10   2.   The method of claim 1 further comprising the step of:

indicating an end of said exchange to allow a next plurality of data frames on said second data channel to be directed to said   specified one of said first data channels.

3.   The method of claim 1 wherein said step of indicating is

15   carried out by means of a Fibre Channel Originator Exchange Identifier.

4.   The method of claim 1 wherein said step of directing is carried out by a Fibre Channel front end in response to directions from an associated matrix controller.

5.   The method of claim 4 wherein said step of also directing

20   is carried out by said Fibre Channel front end.

6.   The method of claim 1 further comprising the step of:

converting a format of said plurality of data frames on said second data channel to a differing format for said plurality of first data channels.

25   7.   The method of claim 6 further comprising the step of:

also converting said differing format for said plurality of data frames on said plurality of first data channels to said format on said second data channel.

8.   The method of claim 7 wherein said steps of converting

30   and also converting are carried out by means of a link controller

9. The method of claim 1 wherein said step of directing further comprises the step of:

storing said first of said plurality of data frames in each of a plurality of buffers respectively associated with each of said plurality of first data channels.

10. The method of claim 9 wherein said step of also directing further comprises the step of:

storing all subsequent ones of said plurality of data frames to one of said plurality of buffers associated with said specified one of said first data channels.

11. A port module comprising:

a plurality of link controllers, each of said link controllers coupled to one of a plurality of data ports;

a plurality of buffer memories, each of said buffer memories associated with each of said link controllers;

a data channel; and

a front end portion of said port module coupled to said data channel and operative in association with a matrix controller for identifying a start up exchange for a first of a plurality of data frames on said data channel, said front end portion directing said first of said plurality of data frames to a first portion of said plurality of buffer memories and all subsequent ones of said plurality of data frames to a second portion of one of said plurality of buffer memories associated with one of said link controllers associated with a selected one of said plurality of data ports specified by said matrix controller.

12. The port module of claim 11 wherein said plurality of data ports comprise ESCON ports.

13. The port module of claim 12 comprising eight ESCON ports.

14.   The port module of claim 11 wherein said data channel is a
Fibre Channel.

15.   The port module of claim 14 wherein said start up
exchange is indicated by an Originator Exchange Identifier for said
5   plurality of data frames.

16.   The port module of claim 11 wherein said first portion of
said buffer memories comprises a start-up descriptor portion.

17.   The port module of claim 11 wherein said second portion
of one of said plurality of buffer memories comprises a cut-through
10   descriptor portion.

18.   The port module of claim 11 wherein said plurality of link
controllers are operative to convert a format of said plurality of data
frames from Fibre Channel to ESCON.

19.   The port module of claim 18 wherein said plurality of link
15   controllers are further operative to convert said format of said plurality
of data frames from ESCON to Fibre Channel.

20.   The port module of claim 11 wherein said plurality of data
ports comprise bidirectional ports of an ESCON cross point switch.

21.   A method for establishing dynamic ESCON connections
20   over a Fibre Channel connection comprising:

receiving a series of Fibre Channel data frames on said Fibre
Channel connection;

checking each of said series of data frames for a status of an
Originator Exchange Identifier;

25   linking said Originator Exchange Identifier to a selected one of a
plurality of link controllers each coupled to one of said ESCON
connections and passing said data frame to said selected one of said
plurality of link controllers if said status of said Originator Exchange
Identifier of a first of said series of data frames is in an inactive state
30   thereof;

changing said state of said Originator Exchange Identifier to an active state thereof;

passing each of said series of data frames having a corresponding Originator Exchange Identifier to said selected one of

5   said plurality of link controllers while said status of said Originator Exchange Identifier is in said active state thereof; and

re-changing said state of said Originator Exchange Identifier to said inactive state thereof upon receipt of a last of said series of data frames having said corresponding Originator Exchange Identifier.

10   22.   The method of claim 21 further comprising:

not linking said Originator Exchange Identifier to a selected one of said link controllers if said Originator Exchange Identifier is in said inactive state thereof and a destination busy frame is generated.
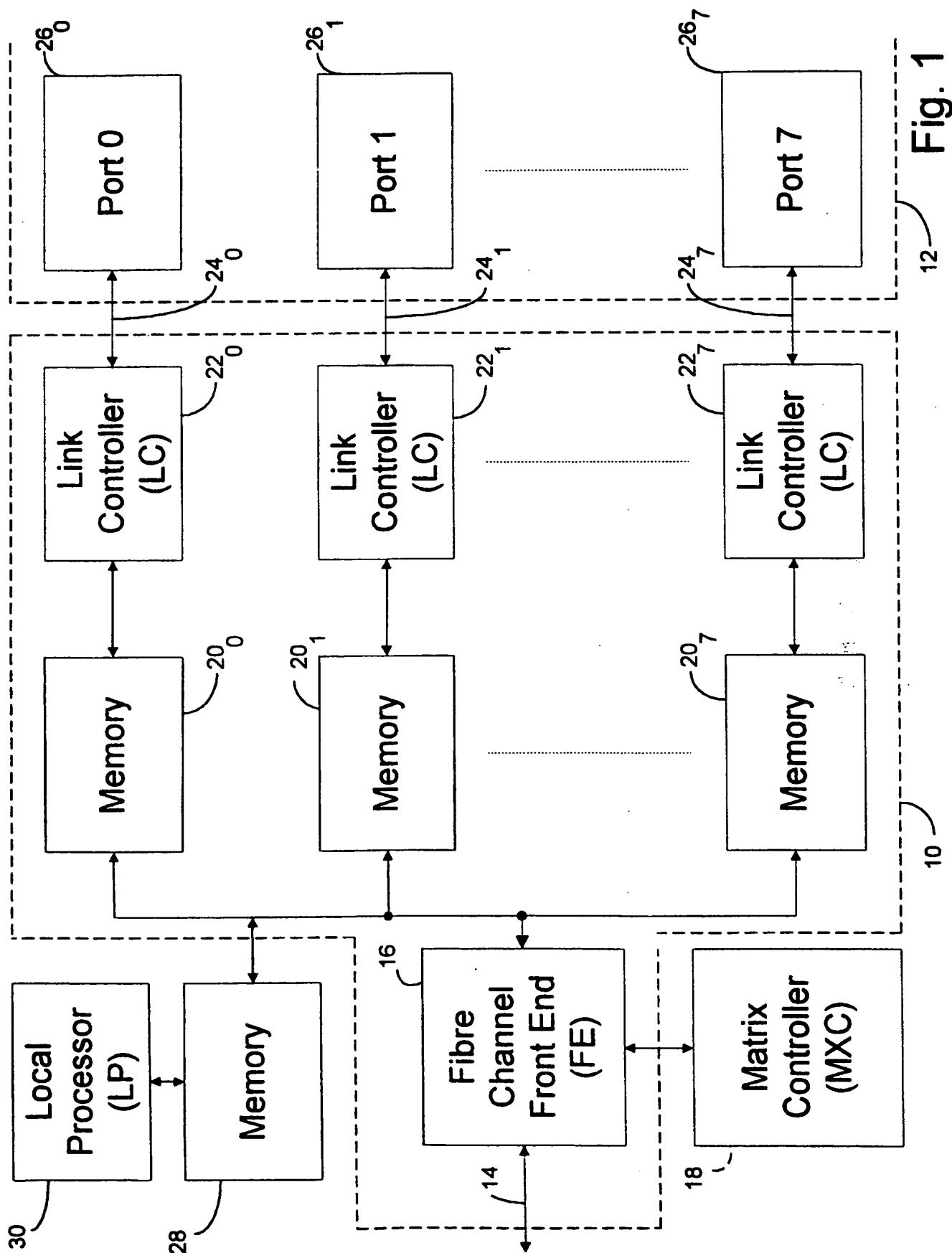
23.   The method of claim 21 wherein said step of not linking

15   said Originator Exchange Identifier to a selected one of said link controllers occurs if said Originator Exchange Identifier is in said inactive state thereof and a source port busy frame is generated.

24.   The method of claim 21 wherein said step of not linking said Originator Exchange Identifier to a selected one of said link

20   controllers occurs if said Originator Exchange Identifier is in said inactive state thereof and a port reject frame is generated.

25.   The method of claim 21 further comprising the step of:

providing a buffer memory associated with each of said plurality of link controllers.

25   26.   The method of claim 25 further comprising the step of:

partitioning said buffer memory into a start-up buffer portion for receiving an initial one of said data frames prior to said step of linking and a cut-through buffer portion for receiving subsequent ones of said data frames passed to said selected one of said plurality of link
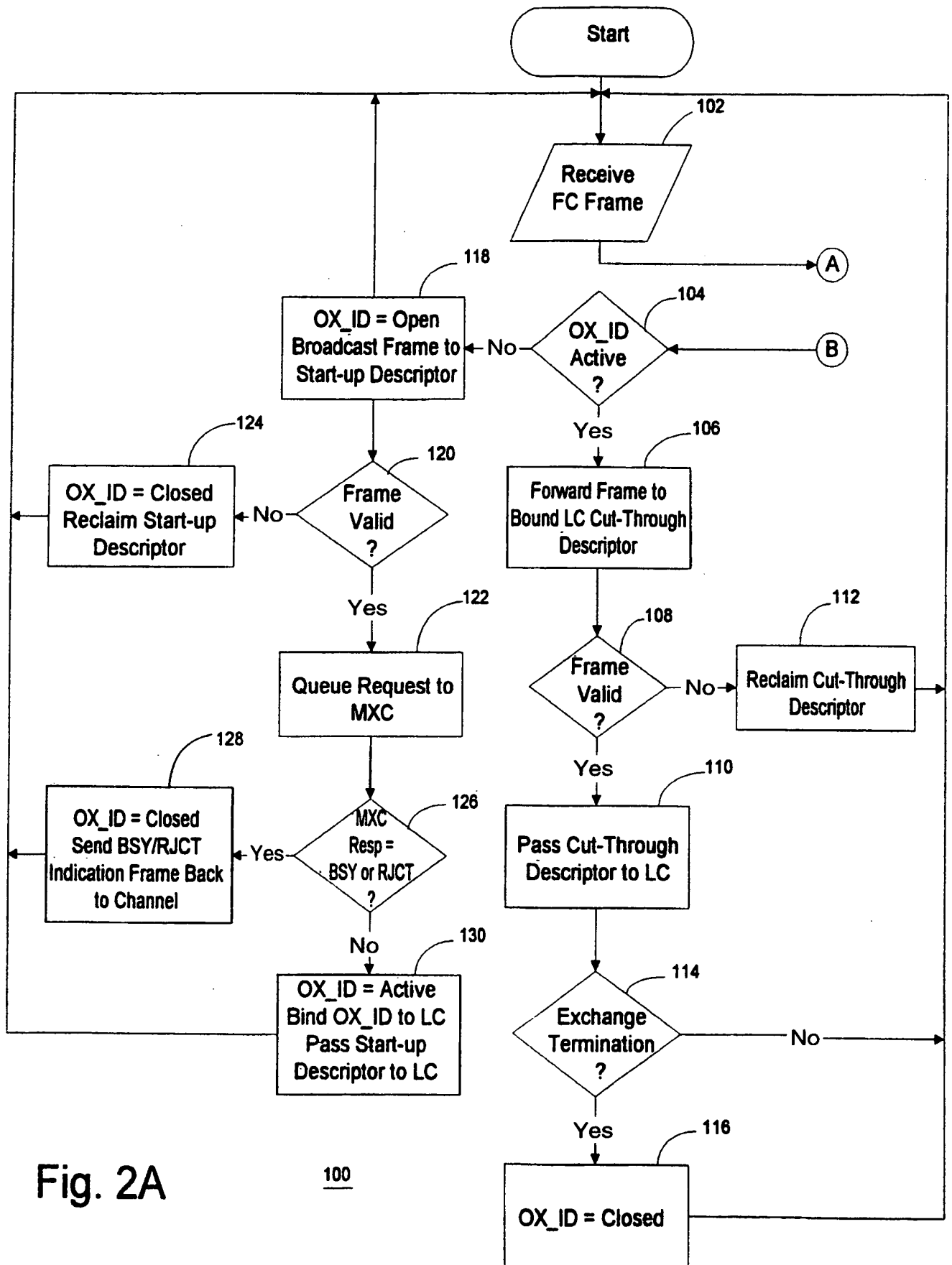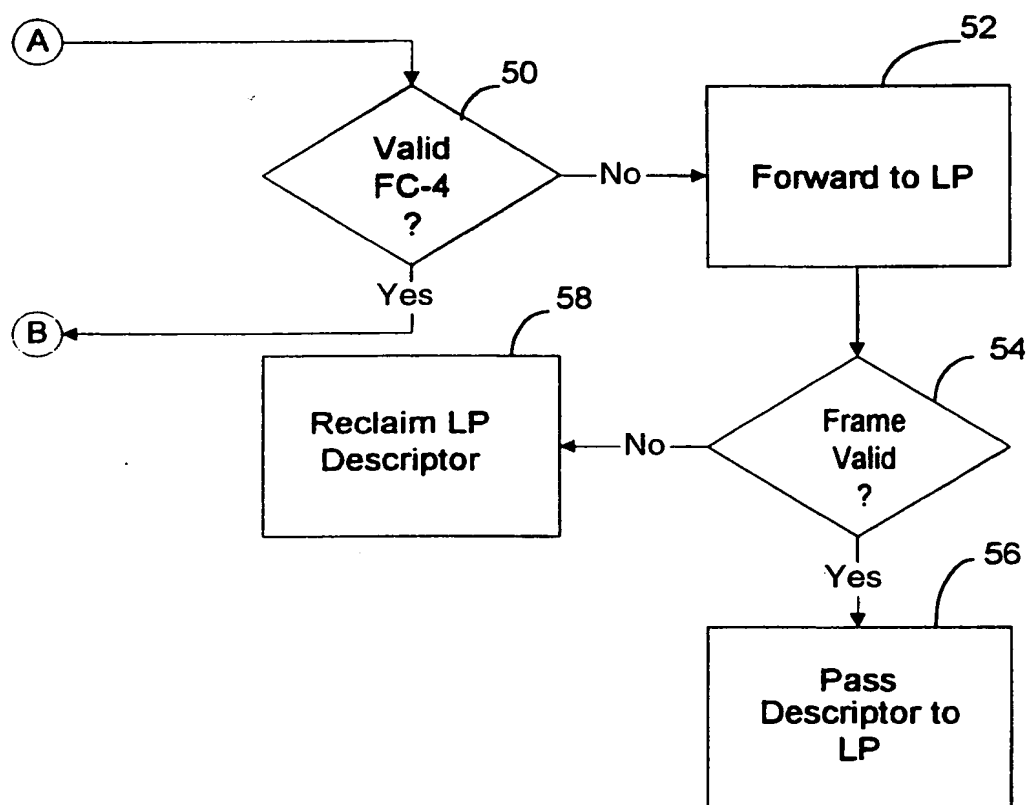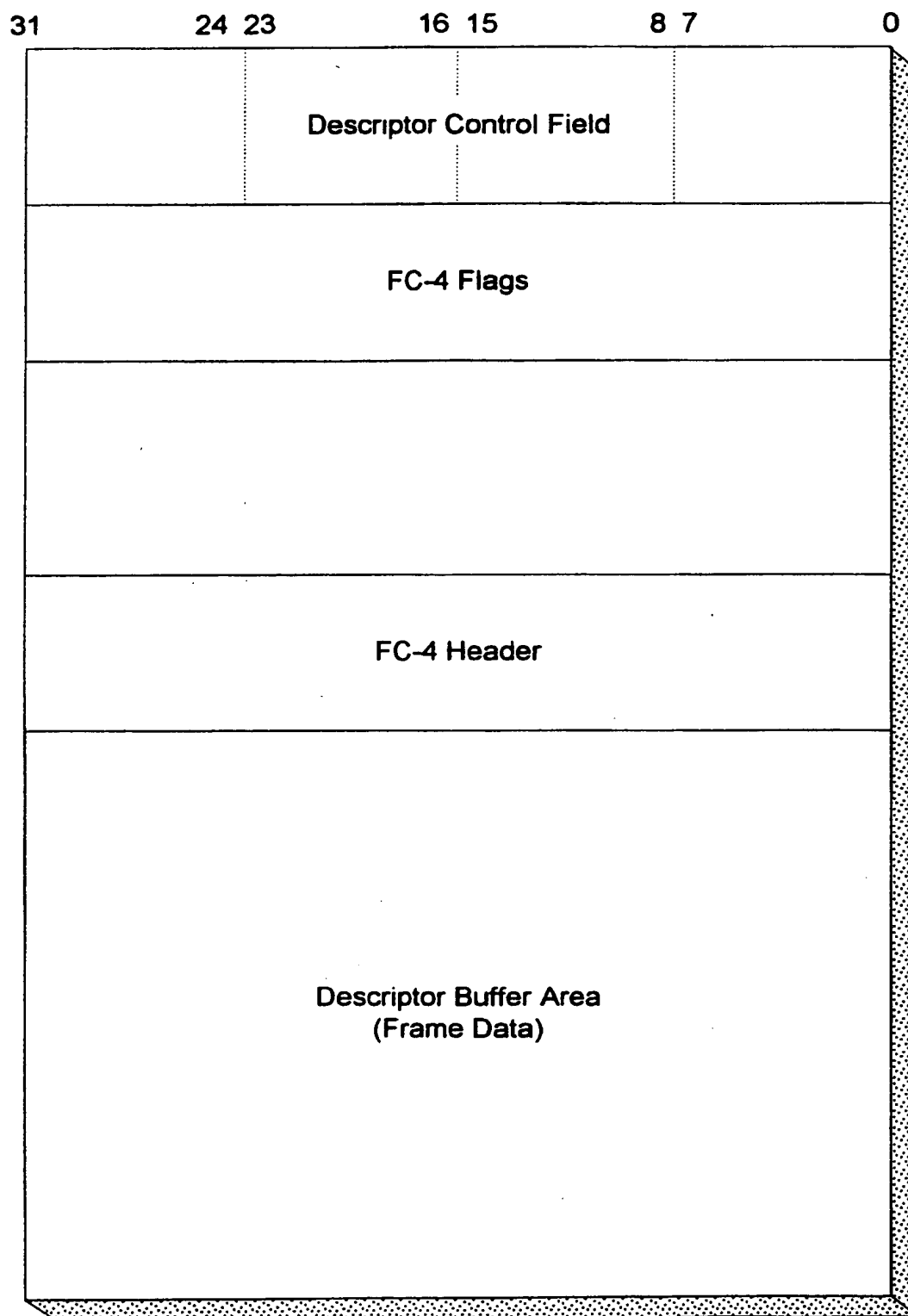
30   controllers.

Fig. 1

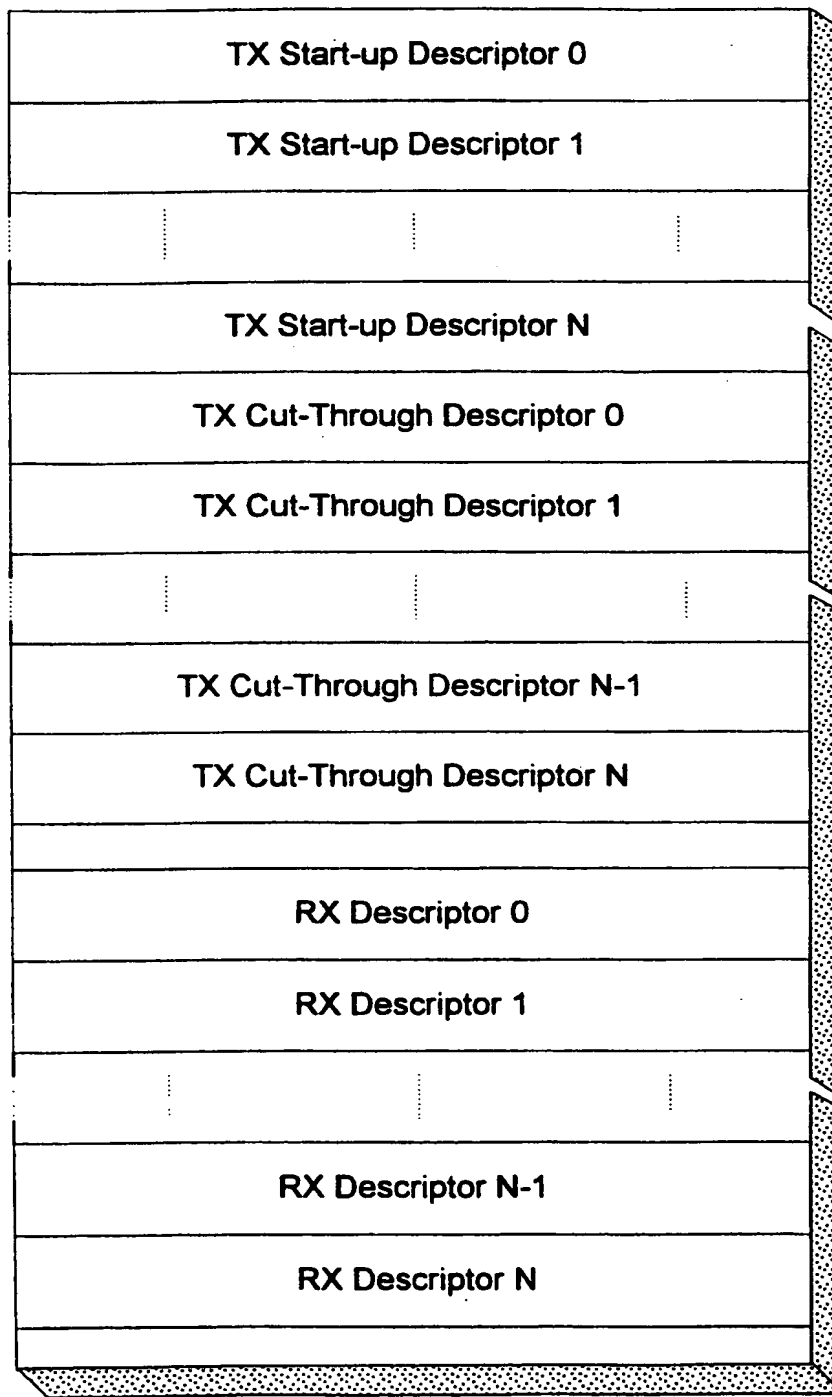**Fig. 2A**   <u>100</u>

Fig. 2B

31		24	23		16	15		8	7		0

Descriptor Control Field

FC-4 Flags

FC-4 Header

Descriptor Buffer Area
(Frame Data)

Fig. 3

TX Start-up Descriptor 0
TX Start-up Descriptor 1
TX Start-up Descriptor N
TX Cut-Through Descriptor 0
TX Cut-Through Descriptor 1
TX Cut-Through Descriptor N-1
TX Cut-Through Descriptor N
RX Descriptor 0
RX Descriptor 1
RX Descriptor N-1
RX Descriptor N

Fig. 4

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US99/00900

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6)   :HO4J 3/16, 3/17
US CL   :370/431, 433, 465, 468; 710/1, 33, 36, 38, 129; 709/228, 250

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. :   370/431, 433, 465, 468; 710/1, 33, 36, 38, 129; 709/228, 250

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Please See Extra Sheet.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,546,549 A (BARRETT et al) 13 August 1996, see col. 11, lines 14 + & Fig 7.	1-26
X	US 5,423,026 A (COOK et al) 6 June 1995, see col. 13, lines 12 + Fig 9.	1-26
X	US 5,699,532 A (BARRETT et al) 16 December 1997, see col. 11, lines 14 + & Fig 7.	1-26
X,P	US 5,805,822 A (LONG et al) 08 September 1998, see Fig 3.	1-26
X,P	US 5,793,983 A (ALBERT et al) 11 August 1998, see Fig 3.	1-26

☐ Further documents are listed in the continuation of Box C.   ☐ See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	
"E" earlier document published on or after the international filing date	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
23 MARCH 1999	11 MAY 1999

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Form PCT/ISA/210 (second sheet)(July 1992)*

B. FIELDS SEARCHED
Electronic data bases consulted (Name of data base and where practicable terms used):

APS
search terms: ESCON, dyanamic channel assignment, simplex, interface, exchange identifier, matrix, buffer, multiplexing, channel selection, allocating channel, converting format

Form PCT/ISA/210 (extra sheet)(July 1992)★